534 Rec'd PCT/PTO 1 8 AUG 2000

FORM PTO-1390 (REV. 12-29-99)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
	TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	S1022/8518

U S APPLICATION NO. (If known, see 37 CFR 1.5)
09/622523

INTERNATIONAL APPLICATION NO. PCT/SE99/00210	INTERNATIONAL FILING DATE 17 February 1999 (17.02.99)	PRIORITY DATE CLAIMED 21 February 1998 (21.02.98)

TITLE OF INVENTION   IMPROVEMENTS IN, OR RELATING TO, VDSL

APPLICANT(S) FOR DO/EO/US   ISAKSSON, Mikael, BENGTSSON, Daniel, SJÖBERG, Frank, ÖDLING, Per, NILSSON, Rickard, BAHLENBERG, Gunnar, JOHANSSON, Magnus, OLSSON, Lennart and ÖKVIST, Göran

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒   This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. ☐   This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. ☒   This express request to begin national procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. ☐   A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ☐   A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
    a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
    b. ☐ has been transmitted by the International Bureau.
    c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).

6. ☐   A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. ☐   Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
    a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
    b. ☐ have been transmitted by the International Bureau.
    c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
    d. ☐ have not been made and will not be made.

8. ☐   A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. ☐   An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. ☐   A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(C)(5)).

Items 11. To 16. Below concern document(s) or information included:

11. ☐   An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. ☐   An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. ☒   A FIRST preliminary amendment.
    ☐   A SECOND or SUBSEQUENT preliminary amendment.

14. ☐   A substitute specification.

15. ☐   A change of power of attorney and/or address letter.

16. ☐   Other items or information: Copy of Published PCT Application WO 99/43123

Express Mail Label No.   EL018092617US
Date Mailed: August 18, 2000

U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/622523	INTERNATIONAL APPLICATION PCT/SE99/00210	ATTORNEY'S DOCKET NUMBER S1022/8518

17.☒ The following fees are submitted:	CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

Neither international preliminary examination fee (37 CFR 1.482)
Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO
And International Search Report not prepared by the EPO or JPO $970.00

International preliminary examination fee (37 CFR 1.482) not paid to
USPTO but International Search Report prepared by the EPO or JPO $840.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but
But international search fee paid to USPTO (37 CFR 1.445(a)(2)).paid to USPTO $690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
But all claims did not satisfy provisions of PCT Article 33(1)-(4) $670.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
And all claims satisfied provisions of PCT Article 33(1)-(4) $96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 970.00	

Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	16 - 20 =	0	X $18.00	$	
Independent Claims	2 - 3 =	0	X $78.00	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+$260.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 970.00	

Reduction by ½ for filing by small entity, if applicable. Verified Small Entity Statement Must also be filed (Note 37 CFR 1.9, 1.27, 1.28).	$	
SUBTOTAL =	$ 970.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(f)).	$	

TOTAL NATIONAL FEE =	$ 970.00	

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate coversheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 970.00	
	Amount to be: refunded	$
	charged	$

a. ☒   A check in the amount of $ 970.00 To cover the above fees is enclosed.

b. ☐   Please charge my Deposit Account No. _____ In the amount of $_____ To cover the above fees.
   A duplicate copy of this sheet is enclosed.

c. ☒   The commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 23/2825. A duplicate of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.

SIGNATURE

SEND ALL CORRESPONDENCE TO·

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REGISTRATION NO

Express Mail Label No. EL018092617US
Attorney's Docket No. S1022/8518

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Serial No.:   Unassigned

Filing Date: Herewith

For: IMPROVEMENTS IN, OR RELATING TO VDSL

Examiner: Unassigned

Art Unit: Unassigned

Box Patent Application
Commissioner For Patents
Washington, D.C. 20231

AMENDMENT

Sir/Madam:

Prior to examination please amendment the above-identified application as follows:

IN THE CLAIMS

Claim 1, line 4, change "characterised in that" to --wherein--;

Claim 2, lines 1 and 2, change "characterised in that" to --wherein--;

Claim 3, lines 1 and 2, change "characterised in that" to --wherein--.

4.   (Amended) A telecommunications system, as claimed in [any previous] claim 1, [characterised in that] wherein said pulse shaped wings are in the form of a raised cosine pulse.

5.   (Amended) A telecommunications system, as claimed in [any previous] claim 1, [characterised in that] wherein the same number of sub-carriers are used for transmission in the up stream direction as are used for transmission in the down stream direction.

6.   (Amended) A telecommunications system, as claimed in [any of claims 1 to 4] claim 1, [characterised in that] wherein a different number of sub-carriers are used for transmission in the up stream and down stream directions.

7.   (Amended) A telecommunications system, as claimed in [any previous] claim 1, [characterised in that] <u>wherein</u> said transmitter comprises [an] a b-bit buffer and encoder for receiving an input bit stream at a rate of R bit/s, [a] <u>an</u> n-point IDFT processor for receiving an output from said b-bit buffer and encoder, extension means for adding a cyclic extension to an output of said IDFT processor, a pulse shaper for shaping a DMT symbol output from said extension means, and a digital to [analogue] <u>analog</u> converter and low pass filter for converting a DMT symbol received from said pulse shaper to [analogue] <u>analog</u> form and passing said DMT to a transmission channel.

8.   (Amended) A telecommunications system, as claimed in [any previous] claim 1, [characterised in that] <u>wherein</u> said receiver includes an [analogue] <u>analog</u> to digital converter for [digitising] <u>digitizing</u> a DMT symbol received from a transmission channel, a windowing unit connected to an output of said [analogue] <u>analog</u> to digital converter, a stripper unit for removing cyclic extensions to said DMT symbol, an n-point DFT processor for receiving an output from said stripper unit, a frequency domain [equalisation] <u>equalization</u> unit for receiving an output from said n-point DFT unit and decoder, and a b-bit buffer for receiving an output from said frequency domain [equalisation] <u>equalization</u> unit and outputting a bit stream at R bit/s.

9.   (Amended) A modem for use in a transmission system as claimed in [any of claims 1-6] claim <u>1</u>, [characterised in that] <u>wherein</u> said modem includes a transmitter as claimed in claim 7.

10.   (Amended) A modem as claimed in [claims] <u>claim</u> 9, [characterised in that] <u>wherein</u> said modem includes a receiver as claimed in claim 8.

11.   (Amended) A method in a telecommunication system having at least two VDSL systems adapted to asynchronous transmit DTM-symbols between each pair of modem<u>s</u> having at least two VDSL systems, each comprising a pair of modems, said at least

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two VDSL systems belonging to a binder group common to both VDSL systems, [characterised by] comprising the steps of:

- in a transmitter in a first modem in a pair of modems
    - cyclic extend a DTM-symbol by way of adding a prefix and a suffix;
    - pulse shaping side lobes of the cyclic extended DMT-symbol;
    - transmit the cyclic extended and pulse shaped DMT-symbol to a transmission channel;
- and in a receiver in a second modem in the pair of modems
    - windowing the DTM-symbol which transmits on the [transmissionchannel] transmission channel by way of multiplying μ samples at the beginning and end of a block of $2N+\mu$ samples; folding and adding $\mu/2$ samples from the beginning of the $2N+\mu$ block of samples to the end of the 2N remaining samples; and folding and adding $\mu/2$ samples from the end of the $2N+\mu$ block of samples to the beginning of the 2N remaining samples, and removing said cyclic extension from a DTM-symbol.

12.   (Amended) A method, as claimed in claim 11 [characterised by] further comprising adding a cyclic extension [is] to DMT symbols, said cyclic extension comprising:

- a suffix which is greater than, or equal to, a channel's propagation delay; and
- a prefix which is greater than, or equal to, a guard time needed to eliminate inter-symbol interference.

13.   (Amended) A method as claimed in claim 11 [or 12], [characterised by] further comprising forming said pulse shaped wings as a raised cosine pulse.

14.   (Amended) A method as claimed in [any of claims 11 to 13] claim 11, [characterised by] further comprising performing said pulse shaping at a transmitter after addition of a cyclic extension to a symbol and prior to digital to [analogue] analog conversion.

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15.   (Amended)   A method as claimed in [any of claims 11 to 14] <u>claim 11</u>, [characterised by] <u>further comprising</u> transmitting the same number of sub-carriers in both an upstream and down stream direction.

16.   Amended)   A method as claimed in [any of claims 11 to 14] <u>claim 11</u>, [characterised by] <u>further comprising</u> transmitting a different number of sub-carriers in the an up stream and down stream direction.

REMARKS

This is a preliminary amendment in which the claims have been amended to place them in better form before initial examination by the Examiner. Favorable action is hereby earnestly solicited.

Respectfully submitted,

by
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ATTORNEY'S DOCKET NO. S1022/8518
DATE: August 18, 2000

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Improvements in, or Relating to, VDSL

The present invention relates to a method of using VDSL zipper duplex transmission in an unsynchronised mode, a system employing VDSL zipper duplex transmission, in an unsynchronised mode, over a common twisted pair cable, a transmission system employing the method, a receiver for use with the transmission system, a transmitter for use with the transmission system and a modem, incorporating a receiver and transmitter, for use with the transmission system.

In our co-pending patent application WO 9706619, there is described a procedure for suppressing near-end crosstalk (NEXT) when using duplex communication, in twisted pair wire networks, in which different sub-carriers are used in the two transmission directions, and in which the subcarriers are orthogonal. Preferably a number of sub-carriers are transmitted in each transmission direction. Alternate sub-carriers are used in each direction. The number of sub-carriers used in one transmission direction may be greater than the number used in the other transmission direction.

In our co-pending patent application, referenced above, the use of Zipper VDSL with time synchronization is described. The present invention complements the earlier invention, in that it enables VDSL Zipper duplex transmission, as described in our co-pending patent application, without time synchronization between different modem pairs over the same twisted copper pair cable, i.e. in the same binder group.

Zipper is a time-synchronized frequency division duplex implementation of discrete multi tone (DMT) modulation. Two communicating Zipper modems transmit DMT symbols simultaneously with a common clock. The Zipper scheme implies that every carrier, in the total set of carriers in the DMT signal, is exclusively chosen to be used for either for the up-stream, or the down-stream, direction. When all transmitters are time synchronized, the near end cross-talk (NEXT) and near end echoes, injected into the received signal, are orthogonal to the desired signal. To ensure the orthogonality between the signal and all the noise sources

originating from DMT signals in the opposite direction, the guard time, with cyclic extension of the symbols between consecutive symbols, must be dimensioned for the maximum propagation delay of the channel. Further, the size of the guard time is minimised by applying timing advance.

Several duplex VDSL systems may share the same twisted pair copper cable. Such systems are referred to as belonging to the same binder group. VDSL systems, using Zipper, which belong to the same binder group, are affected by line attenuation, near end echo and crosstalk. In known Zipper transmission systems, when timing advance is used, all transceivers, in a binding group, start the transmission of each frame at the same time.

There are three types of signal that affect the length of the cyclic extension in each frame:

- the received signal;

- the echo signal caused by imperfect balance of the hybrid and impedance discontinuities in the line; and

- the NEXT signal.

Orthogonality, between the received signal, the echo signal and the NEXT signal, is preserved if each sampled DMT symbol is disturbed by a single frame from each one of the near-end transmitters. Because of this, in order to preserve orthogonality, the cyclic extension has to be dimensioned to cover all impulse responses from the line, the echoes and the NEXT.

However, in certain situations it may be difficult, for practical reasons, or otherwise undesirable, to provide and maintain time synchronization between all transmitters in the same binder group. It is therefore desirable to enable Zipper modems, if necessary, to operate in a non-synchronized mode. In other words, only pairwise synchronisation is maintained between a VTU-O and VTU-R pair. The present invention provides this option for Zipper modems and systems employing

Zipper modems. Thus, the present invention permits different users to transmit time asynchronous DMT frames in the same binder group. However, although this is always possible, a noticeable performance penalty can be expected in many situations because of increased NEXT. One way in which the present invention mitigates increased NEXT is by pulse shaping of DMT frames prior to transmission and providing additional pulse shaping at the receiver. Using pulse shaping at the transmitter has the additional advantage of higher suppression of the side lobes of the DMT spectrum. This increases spectral compatibility with other systems, such as, ADSL and CAP-VDSL.

According to a first aspect of the present invention, there is provided a telecommunications transmission system using zipper having at least two VDSL systems, each comprising a pair of zipper modems, said at least two VDSL systems belonging to a binder group common to both VDSL systems, characterised in that said telecommunications transmission system is adapted to:

- handle zipper transmissions transmitted in said binder group;

- at least partly mitigate NEXT; and

- permit transmissions in a first VDSL system which are asynchronous with transmissions in at least a second VDSL system.

DMT frames may be pulse shaped prior to transmission.

Said pulse shaping may produces an improved suppression of side lobes of said DMT's spectrum.

A cyclic extension may be added to DMT symbols, said cyclic extension comprising:

- a suffix which is greater than, or equal to, a channel's propagation delay; and

- a prefix which is greater than, or equal to, a guard time needed to eliminate inter-symbol interference.

Said pulse shaping may be produced by forming pulse shaped wings on a DMT frame in cyclic extensions of the DMT frame.

Said pulse shaped wings may be in the form of a raised cosine pulse.

Said pulse shaping may be performed at a transmitter, after addition of a cyclic prefix and cyclic suffix, to a symbol and prior to digital to analogue conversion.

A DMT signal received by a receiver may be windowed to further reduce NEXT.

Said windowing may be performed by:

- multiplying μ samples at the beginning and end of a block of $2N+\mu$ samples;

- folding and adding $\mu/2$ samples from the beginning of the $2N+\mu$ block of samples to the end of the $2N$ remaining samples; and

- folding and adding $\mu/2$ samples from the end of the $2N+\mu$ block of samples to the beginning of the $2N$ remaining samples.

The same number of sub-carriers may be used for transmission in the up stream direction as are used for transmission in the down stream direction.

A different number of sub-carriers may be used for transmission in the up stream and down stream directions.

According to a second aspect of the present invention, there may be provided, in a telecommunications transmission system using zipper and having at least two VDSL systems, each comprising a pair of zipper modems, said at least

two VDSL systems belonging to a single binder group common to both VDSL systems, a method of transmission characterised by permitting zipper transmissions of said first and, at least, said second VDSL transmission systems, to be transmitted in said single binder group, where transmission in said first VDSL system are asynchronous with zipper transmission in said second VDSL system and in which the effects of NEXT are, at least partly, mitigated.

DMT frames may be pulse shaped prior to transmission.

Said pulse shaping may produce an improved suppression of side lobes of said DMT's spectrum.

A cyclic extension may be added to DMT symbols, said cyclic extension comprising:

- a suffix which is greater than, or equal to, a channel's propagation delay; and

- a prefix which is greater than, or equal to, a guard time needed to eliminate inter-symbol interference.

Pulse shaped wings may be formed on a DMT frame in the cyclic extensions of the DMT frame.

Said pulse shaped wings may be formed as a raised cosine pulse.

Said pulse shaping may be performed at a transmitter after addition of a cyclic extension to a symbol and prior to digital to analogue conversion.

A DMT signal received by a receiver may be windowed to further reduce NEXT.

The following steps may be used to perform said windowing:

- multiplying μ samples at the beginning and end of a block of $2N+\mu$

samples;

- folding and adding µ/2 samples from the beginning of the 2N+µ block of samples to the end of the 2N remaining samples; and

- folding and adding µ/2 samples from the end of the 2N+µ block of samples to the beginning of the 2N remaining samples.

The same number of sub-carriers may be transmited in both an upstream and down stream direction.

A different number of sub-carriers transmited in the up stream and down stream directions.

According to a third aspect of the present invention, there is provided a transmitter, for use in a transmission system as set forth in any preceding paragraph, characterised in that said transmitter comprises an a b-bit buffer and encoder for receiving an input bit stream at a rate of R bit/s, a n-point IDFT processor for receiving an output from said b-bit buffer and encoder, extension means for adding a cyclic extension to an output of said IDFT processor, a pulse shaper for shaping a DMT symbol output from said extension means, and a digital to analogue converter and low pass filter for converting a DMT symbol received from said pulse shaper to analogue form and passing said DMT to a transmission channel.

Said pulse shaper may form pulse shaped wings on said DMT symbol as raised cosine pulses.

According to a fourth aspect of the present invention, there is provided a receiver, for use in a transmission system as set forth in any preceding paragraph, characterised in that said receiver includes an analogue to digital converter for digitising a DMT symbol received from a transmission channel, a windowing unit connected to an output of said analogue to digital converter, a stripper unit for removing cyclic extensions to said DMT symbol, an n-point DFT processor for

receiving an output from said stripper unit, a frequency domain equalisation unit for receiving an output from said n-point DFT unit and decoder, and a b-bit buffer for receiving an output from said frequency domain equalisation unit and outputting a bit stream at R bit/s.

Said windowing unit may perform the following operations:

- multiplying μ samples at the beginning and end of a block of 2N+μ samples;

- folding and adding $\mu/2$ samples from the beginning of the 2N+μ block of samples to the end of the 2N remaining samples; and

- folding and adding $\mu/2$ samples from the end of the 2N+μ block of samples to the beginning of the 2N remaining samples.

According to a fifth aspect of the present invention, there is provided a modem, for use in a transmission system as set forth in any preceding paragraph, characterised in that said modem includes a transmitter as set forth in any preceding paragraph.

Said modem may include a receiver, as set forth in any preceding paragraph.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates the generation of interference signals, cross-talk and echo, that affect the orthogonality of Zipper.

Figure 2 illustrates sampling, at the VTU-O side, of a received frame disturbed by frames from near end transmitters.

Figure 3 illustrates a DMT transmitter/receiver pair for down-stream

transmission, exemplifying symmetric communication where every second sub-carrier is used, respectively, for the up (u), and down-stream (d), directions.

Figure 4 illustrates the frame format for zipper.

Figure 5 illustrates non-orthogonal NEXT.

Figure 6 illustrates pulse shaping of the DMT frame.

Figure 7 is a schematic illustration of the pulse shaping process in the transmitter and the windowing process in the receiver.

Figure 8 illustrates windowing of a received DMT frame.

Figure 9 illustrates asynchronous non-orthogonal NEXT with and without windowing and pulse shaping.

To fully appreciate the operation of the present invention it is necessary to consider the invention disclosed in our earlier co-pending patent application WO 9706619. As previously explained, the present invention enables Zipper to be used in a manner in which VDSL systems operating in the same binder group can operate without mutual synchronisation between each system.

Zipper, as disclosed in our co-pending patent application WO 9706619, is a time-synchronized frequency-division duplex implementation of discrete multi tone (DMT) modulation. Two communicating Zipper modems transmit DMT symbols simultaneously with a common clock. The Zipper scheme implies that every carrier, in the total set of carriers in the DMT signal, is selected for use in either the up-stream, or the down-stream, direction. When all transmitters are time synchronized, the near end cross-talk (NEXT) and near end echoes injected into the received signal, are orthogonal to the desired signal. To ensure that orthogonality is maintained between the signal and all the noise sources, originating from DMT signals in the opposite direction, the guard time with cyclic extension of the symbols,

between consecutive symbols, must be dimensioned for the maximum propagation delay of the channel. Further, the size of the guard time is minimized by applying timing advance.

Figure 1 depicts how two VDSL systems, sharing the same cable, i.e. in the same binder group, are affected by line attenuation, near end echo and cross-talk. Sources of interference that can be identified include:

- echo generated within the hybrids and passed from the transmitters to the receivers;

- NEXT which passes between the transmitter - receiver pairs at the near end; and

- FEXT which passes between the transmitter - receiver pairs at the far end and is transmitted over the full cable length.

When timing advance is used, all transceivers start the transmission of each frame at the same time. There are three types of signals that affect the length of the cyclic extension in each frame: the received signal, the echo-signal due to imperfect balance of the hybrid and impedance discontinuities in the line, and finally the NEXT signal. Figure 2 shows sampling at the VTU-O side of received frame disturbed by frames from near-end transmitters.

As can be seen from Figure 2, the orthogonality between the desired part of the received signal and the disturbances (interference signals) is preserved if each sampled DMT symbol is disturbed by a single frame from each one of the near-end transmitters. As a consequence, to preserve orthogonality, the cyclic extension has to be dimensioned to cover all impulse responses from the line, the echoes, and the NEXT.

The management of the capacity split between up-stream and down-stream is performed by assigning individual carriers for both directions. For example, if a fully symmetric service is required, sub-carriers with even indices can be assigned

to the up-stream and sub-carriers with odd indices can be assigned to the down-stream. Similarly, for an asymmetric 8:1 split, each ninth carrier can be assigned to the up-stream and the other carriers assigned to the down-stream. However, for the sake of spectral compatibility with other existing and future systems, operating on the same cable, alternative carrier assignments can be used.

The transmission and reception of symbols is performed simultaneously at both ends by the VTU-O and by the VTU-R. For down-stream transmission the bit stream is encoded by the VTU-O transmitter into a set of quadrature amplitude modulated (QAM) sub-symbols, where each QAM sub-symbol represents a number of bits determined by the signal-to-noise ratio (SNR) of its associated down-stream sub-channel, the desired overall error probability, and the target bit rate. The set of sub-symbols is then input, as a block, to a complex-to-real discrete Fourier transform (IDFT) processor, see Figure 3. Following the IDFT, a cyclic prefix is added to the output samples to eliminate intersymbol interference, and a cyclic suffix is appended to the output samples to maintain orthogonality between the desired signal and near-end distorting signals. The result is then converted from digital to analog format and applied to the channel.

Thus, the input bit stream, see Figure 3, enters a b-bit buffer and encoder, from which its is passed to the N-point IDFT processor and thence to the cyclic extension adder. Following which the signal is passed via the DAC and lowpass filter to the channel.

At the VTU-R receiver, after analog-to-digital conversion, the cyclic prefix and suffix are stripped, and the samples are transformed back to the frequency domain by a DFT. Each output value used for down-stream transmission is then scaled by a single complex number to compensate for the magnitude and the phase of each down-stream sub-channel's attenuation, and a detector decodes the resulting symbols. The multiplication with this set of complex numbers, one per down-stream sub-channel, is called frequency-domain equalization (FEQ). Figure 3 shows a block diagram of a DMT transmitter and receiver pair, assuming a noiseless channel.

In the steady-state, the subchannel SNRs are monitored in a data-driven manner by the VTU-R during down-stream symbol periods, and the bit distribution is modified, as necessary, at the VTU-O, to optimize system performance. Upon detecting a degradation, or improvement, in one, or more, sub-channel SNRs, the VTU-R computes a modified bit distribution that better meets the desired error performance. Depending on the SNR of a degraded sub-channel, some, or all, of its bits may be moved, via a bit swap algorithm, to one, or more, other sub-channels that can support additional bits. The bit distribution change is reported to the VTU-O, where it is implemented.

For up-stream transmission, the roles of the VTU-O and VTU-R are reversed, that is, transmission and reception are performed on the up-stream set of sub-channels and the operations described above are the same.

The frequency range from zero to 11.04 MHZ is partitioned into 2,048 sub-channels. The Nyquist carrier (sub-channel 2,048) and the dc carrier (sub-channel 0) are not be used for data.

Transmission may occur on up to 2047 sub-carriers, although those sub-carriers overlapping the POTS, ISDN, and amateur radio frequency bands are typically not used in the default configuration. The lowest sub-channel available to support data transmission is dependent on the POTS/ISDN splitter design.

The frame format for Zipper comprises two parts, namely:

-   the DMT symbol; and

-   the cyclic extension.

Orthogonality is maintained between the received signal and interfering DMT signals transmitted in the opposite direction, if they are sufficiently aligned in time. This requirement is fulfilled by the addition of a cyclic extension to the DMT symbol and the use of timing advance (TA). For the ease of description, the cyclic extension can be divided into a cyclic prefix and a cyclic suffix, where:

- the suffix is greater than, or equal to, the propagation delay of the channel; and

- the prefix is greater than, or equal to, the guard time needed to eliminate inter-symbol interference.

Figure 4 illustrates the frame format for zipper.

When timing advance is used all transmitters commence transmission at the same time. The suffix part of the cyclic extension can be treated as an extra guard time required to maintain orthogonality between the up and down-stream channels along the wire line. To fulfil the orthogonality requirement at the receiver, the cyclic extension (prefix + suffix) must also cover the impulse response of the NEXT and the echo signal.

The first L_{cs} samples of the IDFT output are appended to the block of 4096 time-domain samples x_k. The last L_{cp} samples of the IDFT output are prepended to the block. The frame of samples is then read out to the digital-to-analog converter (DAC), see Figure 3, in sequence. That is, the subscripts k of the DAC samples in the sequence are $(4096-L_{cp}),...,4095,0,1,...4094,0,1,...(L_{cs} - 1)$.

The length of the cyclic extension (L_{cp} and L_{cs}) is typically a programmable entity set by the network operator.

In order to maximize high duplex efficiency, timing advance can be used so that the VTU-O transmitters and the VTU-R transmitters start transmitting each DMT frame at the same time. During the reception, a DMT symbol is only disturbed by single symbols, not affected by IFI, in the other direction due to the cyclic extension.

Zipper is a duplexing scheme based on the Discrete Multitone Modulation (DMT) line-coding technique and was invented at Telia Research in 1995. A patent application, SE 952775 (corresponding to WO9706619) was filed on 4th August 1995.

In certain situations, it may be difficult for practical reasons, or it may be undesirable, to provide and maintain time synchronization between all transmitters in the same binder group. It is therefore desirable to provide an option for Zipper modems which enables them to operate in a non-synchronized mode, where only pairwise synchronization is maintained between a VTU-O and VTU-R pair. Thus, the present invention allows different users to transmit time-asynchronous DMT frames in the same binder group. However, although this is always possible, a noticeable performance penalty, due to increased NEXT, is to be expected in many situations. One possible method of mitigating this is to use pulse shaping of the DMT frames prior to transmission and additional pulse shaping in the receiver. The use of pulse shaping at the transmitter results in a higher suppression of the side lobes of the DMT signal spectrum and gives higher spectral compatibility with other systems, for example, ADSL and CAP-VDSL.

When different pairs of transceivers (modems) operating in the same binder group are asynchronous, interference from NEXT will be introduced, because, the NEXT becomes non-orthogonal and therefore degrades the performance. The reason for the NEXT becoming non-orthogonal is that the received and sampled DMT frame will include NEXT from two consecutive DMT frames which are discontinuous, as depicted in Figure 5.

In order to be able to operate in a non-synchronized mode it is necessary to suppress the NEXT by narrowing its out-of-band spectrum which interferes with the spectrum of the received signal. This can be effected by pulse shaping the DMT frame before transmission.

Pulse shaping a DMT frame is performed by forming pulse-shaped wings, e.g. from a raised cosine pulse, in the cyclic extensions of the frame as shown in Figure 6.

With pulse shaping a continuous phase is created between succeeding frames which suppresses the NEXT-interfering sub-carriers' side lobes.

The pulse shaping operation is performed at the transmitter after the cyclic extension is added to the symbol and before the digital to analog conversion (DAC) is performed. The position of the pulse shaping unit is depicted in Figure 7 which shows a block diagram of a transceiver/modem according to the present invention. The construction and operation of a VDSL modem will be immediately apparent to those skilled in the art from, Figure 7, without further explanation. However, for the sake of completeness a brief description of Figure 7 is set out below.

The transmitter arm of the modem is shown at the top of Figure 7. The input bit stream, at Rbits/s, is passed to a n-bit buffer and encoder from whence a parallel signal, $Xd_{1,k}$, $Xu_{2,k} = 0$ ....$Xd_{N-1,k}$, $Xu_{N,k} = 0$, is passed to an n-point IDFT processor. The output from the IDFT processor, $x_{1,k}$, $x_{2,k}$ ......$x_{N,k}$, is then passed to a unit, P/S, where the cyclic extensions, both prefix and suffix, are added to the DMT symbol. The DMT symbol with cyclic extensions then passes to a pulse shaping unit where the pulse is shaped as described above. The DMT symbol is then passed to a digital to analogue convertor and low pass filter and thence to the transmission channel.

The receiver arm of the modem is shown at the bottom of Figure 7. An incoming signal from the channel is first passed, via a low pass filter and analogue to digital convertor, to a windowing unit, see below for further details. The symbols are then passed to a stripper unit which strips off the cyclic extensions, both prefix and suffix, and thence, as a signal $y_{1,k}$, $y_{2,k}$ .... $y_{N,k}$, to a n-point DFT processor. The signal, $Yd_{1,k}$, $Yu_{2,k}$ ......$Yd_{N-1,k}$, $Yu_{n,k}$, is then passed to a frequency domain equaliser, FEQ, see the description of Figure 3, and thence to a decoder and n-bit buffer, as a signal $Xd_{1,k}$, $Xu_{2,k}$ .... $Xd_{N-1,k}$, $Xu_{N,k}$, which outputs the received data stream at R bits/s.

Windowing the received DMT frame, as shown in Figure 8, further suppresses the non-orthogonal NEXT. The windowing is performed by multiplying μ samples, at both the beginning and end of the $2N+\mu$ block of samples. The $\mu/2$ samples from both ends are folded and added to the 2N remaining block of samples at the opposite ends as shown in Figure 8. As with the pulse shaping of

the DMT frames in the transmitter, the windowing in the receiver creates a continuous phase of the non orthogonal NEXT signals. The positioning of the windowing is shown in Figure 8.

5   Figure 9 shows the combined effect, on the non-orthogonal NEXT, of pulse shaping the DMT-frame in the transmitter and windowing the received frame in the receiver. Figure 9 also shows the signal energy, the NEXT reference signal without pulse-shaping and windowing, the NEXT signal after pulse-shaping and windowing and the FEXT signal at each sub-carrier. As seen in the figure, more than 25 dBm/Hz further suppression can be obtained by both pulse shaping and windowing.

CLAIMS

1. A telecommunications transmission system having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a binder group common to both VDSL systems, characterised in that

   - a transmitter in a first modem in a pair of modem including

        -     a extension means (P/S) for cyklic extension of a DMT-symbol by way of adding a prefix or a suffix,

        -     a pulse shaper means, adapted to pulseshape sidelobes of a cyclic extended DMT-symbol, and futher

   - a receiver in a second modem in a pair of modem including

        -     windowing means adapted to multiplying μ samples at the beginning and end of a block of $2N+\mu$ samples; folding and adding $\mu/2$ samples from the beginning of the $2N+\mu$ block of samples to the end of the 2N remaining samples; and folding and adding $\mu/2$ samples from the end of the $2N+\mu$ block of samples to the beginning of the 2N remaining samples.

        -     a stripping means (s/p) for removing said cyclic extension from a DTM-symbol.

2. A telecommunications system, as claimed in claim 1, characterised in that said modem is a Zippermodem.

3.   A telecommunications system as claimed in claim 1, characterised in that said cyclic extension comprising:

        -     a suffix which is greater than, or equal to, a channel's propagation delay; and

        -     a prefix which is greater than, or equal to, a guard time

needed to eliminate inter-symbol interference.

4.   A telecommunications system, as claimed in any previous claim, characterised in that said pulse shaped wings are in the form of a raised cosine pulse.

5.   A telecommunications system, as claimed in any previous claim, characterised in that the same number of sub-carriers are used for transmission in the up stream direction as are used for transmission in the down stream direction.

6.   A telecommunications system, as claimed in any of claims 1 to 4, characterised in that a different number of sub-carriers are used for transmission in the up stream and down stream directions.

7.   A telecommunications system, as claimed in any previous claim, characterised in that said transmitter comprises an a b-bit buffer and encoder for receiving an input bit stream at a rate of R bit/s, a n-point IDFT processor for receiving an output from said b-bit buffer and encoder, extension means for adding a cyclic extension to an output of said IDFT processor, a pulse shaper for shaping a DMT symbol output from said extension means, and a digital to analogue converter and low pass filter for converting a DMT symbol received from said pulse shaper to analogue form and passing said DMT to a transmission channel.

8. A telecommunications system, as claimed in any previous claim, characterised in that said receiver includes an analogue to digital converter for digitising a DMT symbol received from a transmission channel, a windowing unit connected to an output of said analogue to digital converter, a stripper unit for removing cyclic extensions to said DMT symbol, an n-

point DFT processor for receiving an output from said stripper unit, a frequency domain equalisation unit for receiving an output from said n-point DFT unit and decoder, and a b-bit buffer for receiving an output from said frequency domain equalisation unit and outputting a bit stream at R bit/s.

9. A modem for use in a transmission system as claimed in any of claims 1-6, characterised in that said modem includes a transmitter as claimed in claim 7.

10. A modem as claimed in claims 9, characterised in that said modem includes a receiver as claimed in claim 8.

11. A method in a telecommunication system having at least two VDSL systems adapted to asynchronous transmit DTM-symbols between each pair of modem having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a binder group common to both VDSL systems, characterised by the step of

- in a transmitter in a first modem in a pair of modem

  - cyclic extend a DTM-symbol by way of adding a prefix and a suffix;

  - pulse shaping side lobes of the cyclic extended DMT-symbol;

  - transmit the cyclic extended and pulse shaped DMT-symbol to a transmission channel:

- and in a receiver in a second modem in the pair of modem

  - windowing the DTM-symbol which transmits on the transmissionchannel by way of multiplying μ samples at the beginning and end of a block of $2N+\mu$ samples; folding and adding $\mu/2$ samples from the beginning of the $2N+\mu$ block of samples to the end of the 2N remaining samples; and folding

and adding µ/2 samples from the end of the 2N+µ block of samples to the beginning of the 2N remaining samples, and

- removing said cyclic extension from a DTM-symbol.

12. A method, as claimed in claim 11 characterised by adding a cyclic extension is to DMT symbols, said cyclic extension comprising:

- a suffix which is greater than, or equal to, a channel's propagation delay; and

- a prefix which is greater than, or equal to, a guard time needed to eliminate inter-symbol interference.

13. A method as claimed in claim 11 or 12, characterised by forming said pulse shaped wings as a raised cosine pulse.

14. A method as claimed in any of claims 11 to 13, characterised by performing said pulse shaping at a transmitter after addition of a cyclic extension to a symbol and prior to digital to analogue conversion.

15. A method as claimed in any of claims 11 to 14, characterised by transmitting the same number of sub-carriers in both an upstream and down stream direction.

16. A method, as claimed in any of claims 11 to 14, characterised by transmitting a different number of sub-carriers in the up stream and down stream directions.

ABSTRACT

Improvements in, or Relating to, VDSL

Zipper is a time-synchronized frequency-division duplex implementation of discrete multi tone (DMT) modulation. Two communicating Zipper modems transmit DMT symbols simultaneously with a common clock. The Zipper scheme implies that every carrier, in the total set of carriers in the DMT signal, is exclusively chosen to be used for either the up-stream or the down-stream direction. When all transmitters are time synchronized, the near end cross-talk (NEXT) and near end echoes injected into the received signal are orthogonal to the desired signal.

The present invention provides s telecommunications transmission system using zipper and having at least two VDSL systems. Each of VDSL system comprises a pair of zipper modems communicating over a cable transmission path. The two VDSL systems employing a common cable. The telecommunications transmission system is adapted to:

-      handle zipper transmissions transmitted over the common cable;

-      at least partly mitigate NEXT; and

-      permit transmissions in a first VDSL system which are asynchronous with transmissions in a second VDSL system.
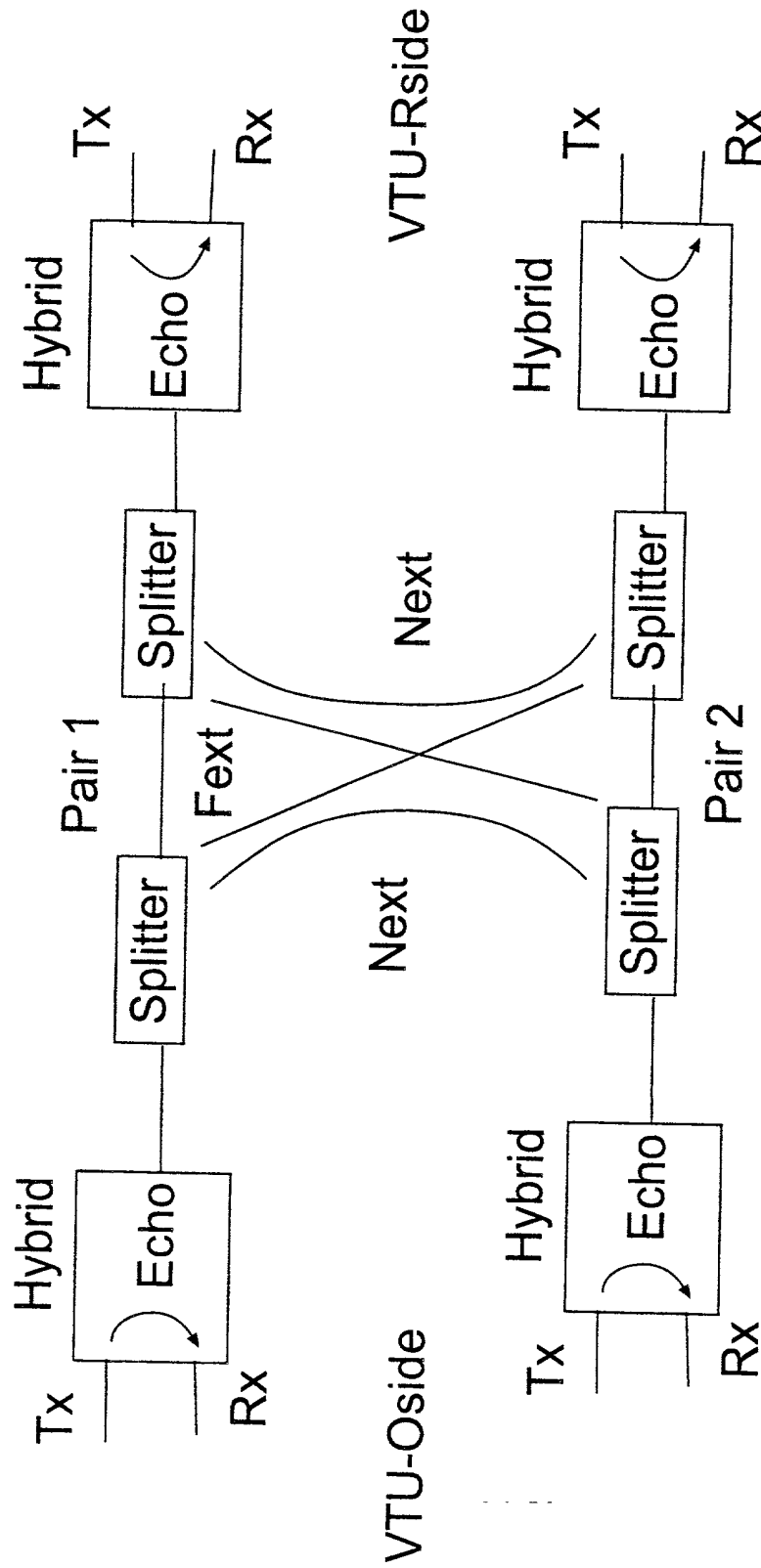
Figure 1

FIGURE 2

Fig 3

Input bit stream

b-bit buffer and encoder

$Xd_{1,k}$

$Xu_{2,k}=0$

$Xu_{N-1,k}=0$

N-pt IDFT

$X_{1,k}$

$X_{2,k}$

$X_{N,k}$

P/S and add cyclic extensions

DAC and lowpass filter

Channel

ADC and lowpass filter

Strip cyclic extension and S/P

$Y_{1,k}$

$Y_{2,k}$

$Y_{N,k}$

N-pt DFT

$Yd_{1,k}$

$Yu_{2,k}$

$Yd_{N-1,k}$

$Yu_{N,k}$

FEQ

$Xd_{1,k}$

$Xu_{2,k}$

$Xd_{N-1,k}$

$Xu_{N,k}$

Decoder and b-bit buffer

Output bit stream

R bits/s
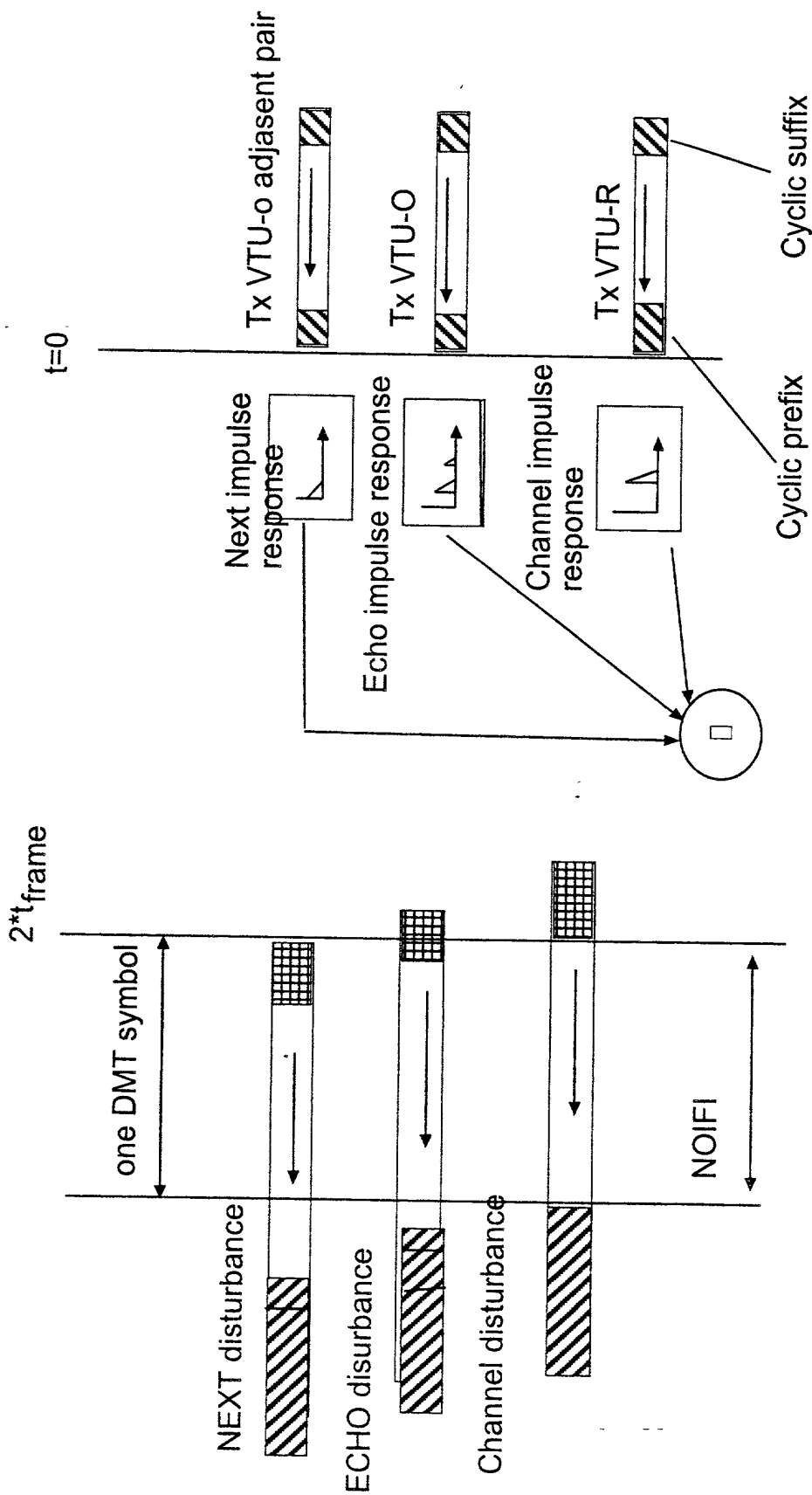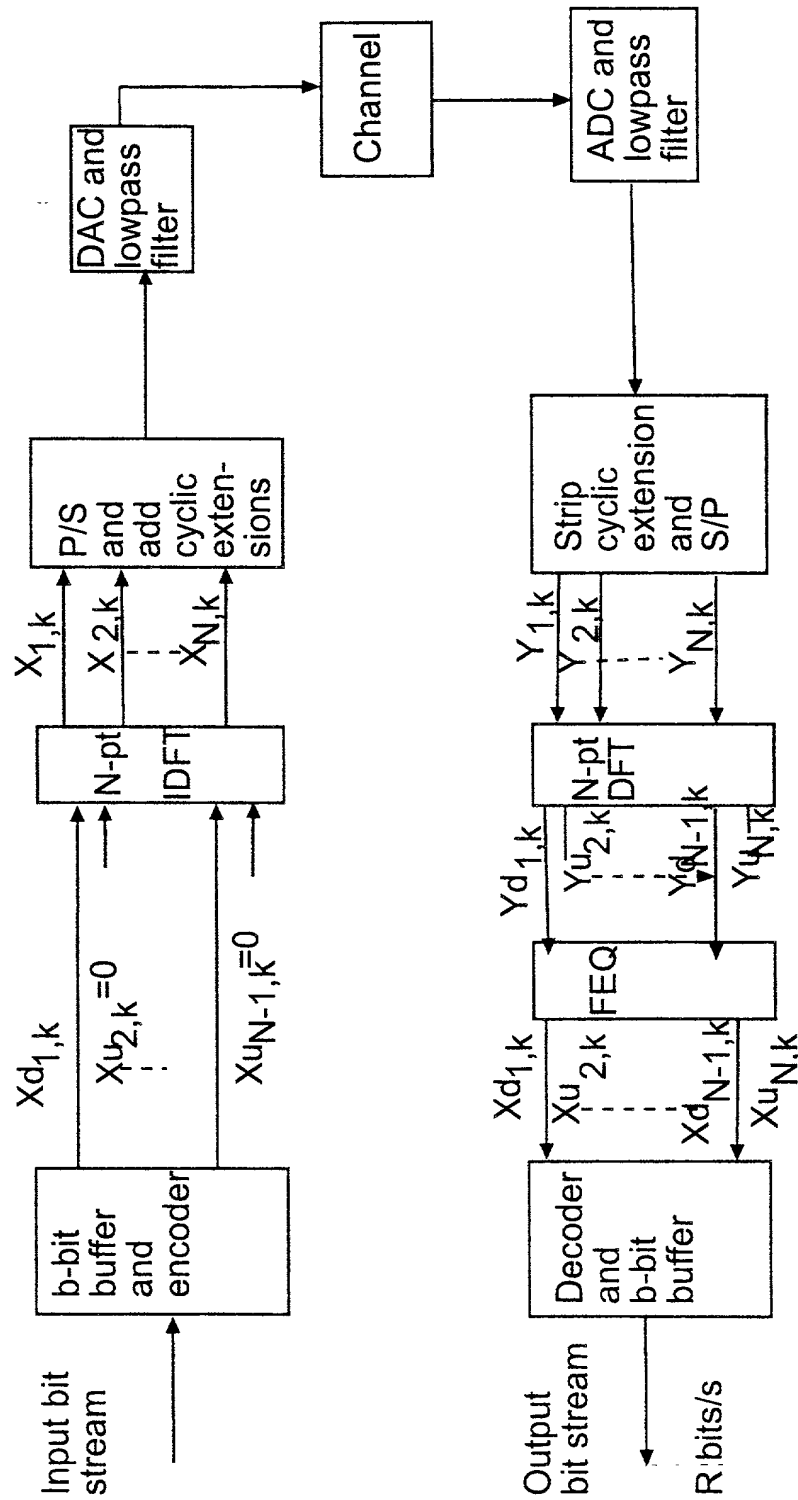
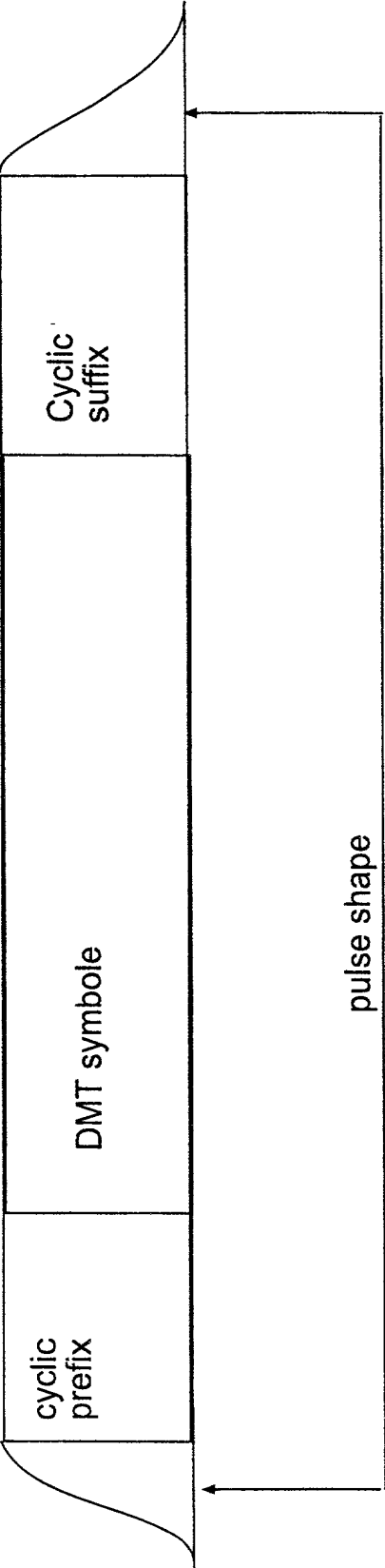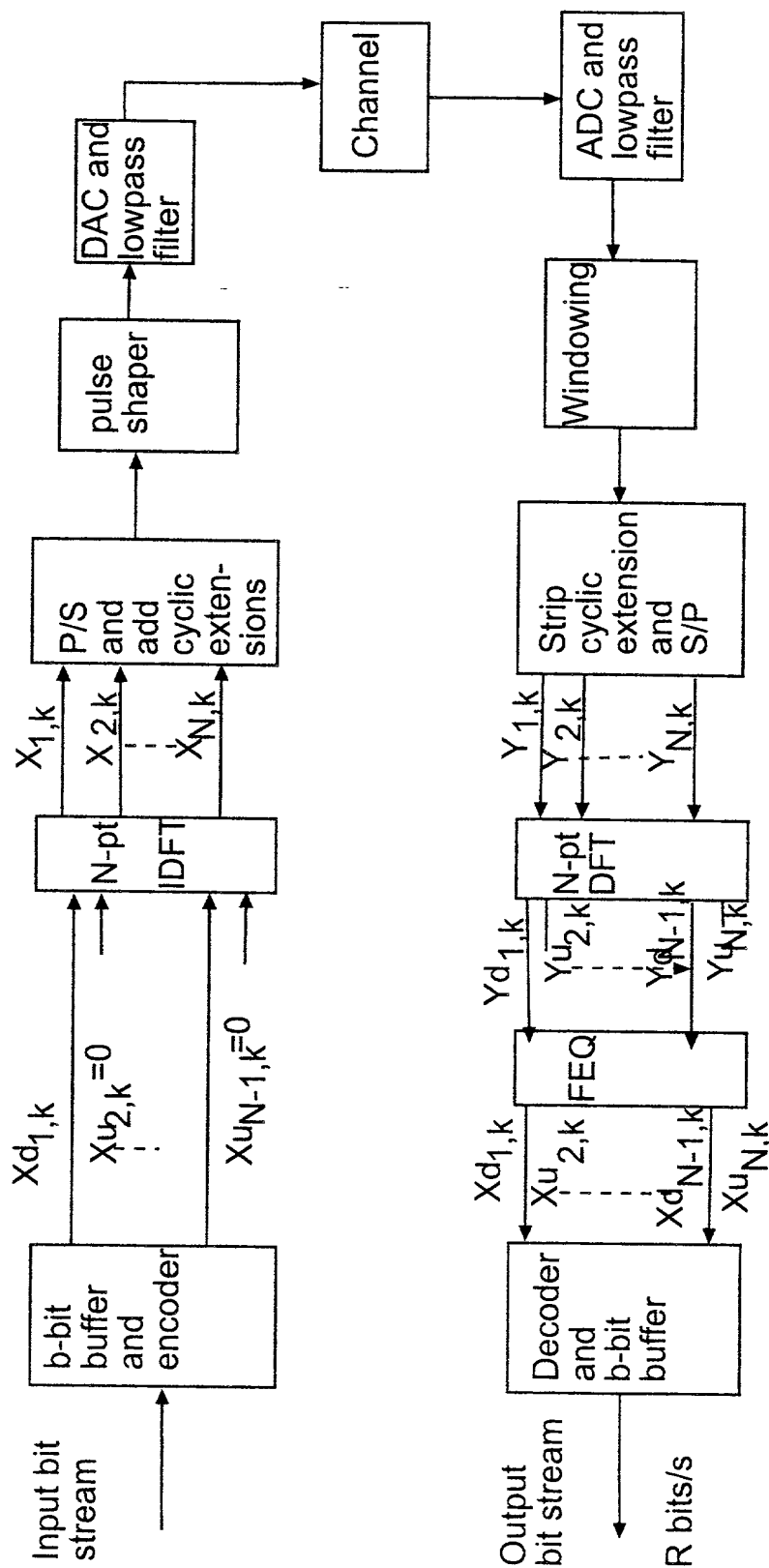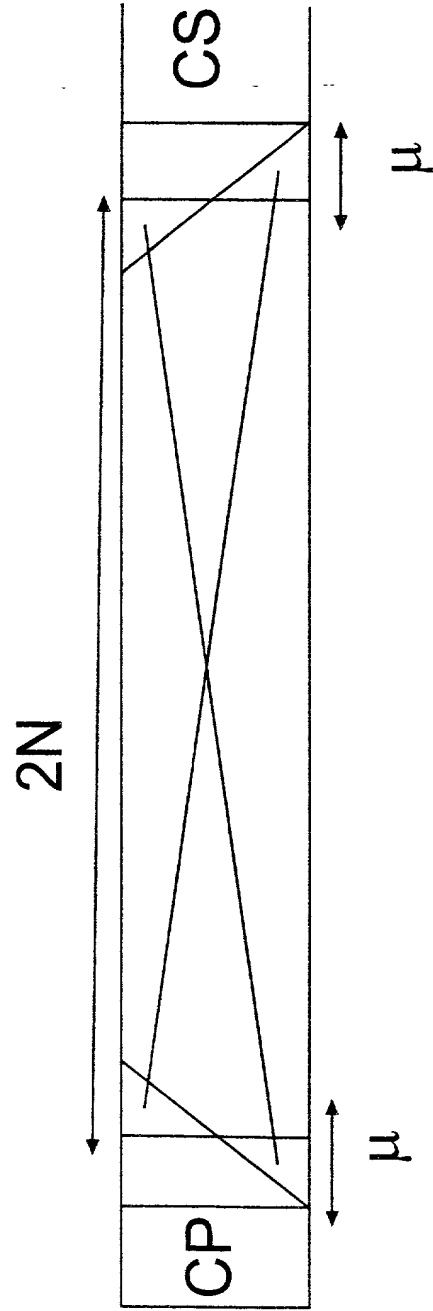| cyclic prefix	DMT symbol	cyclic suffix

Figure 4

Figure 5

Figure 6
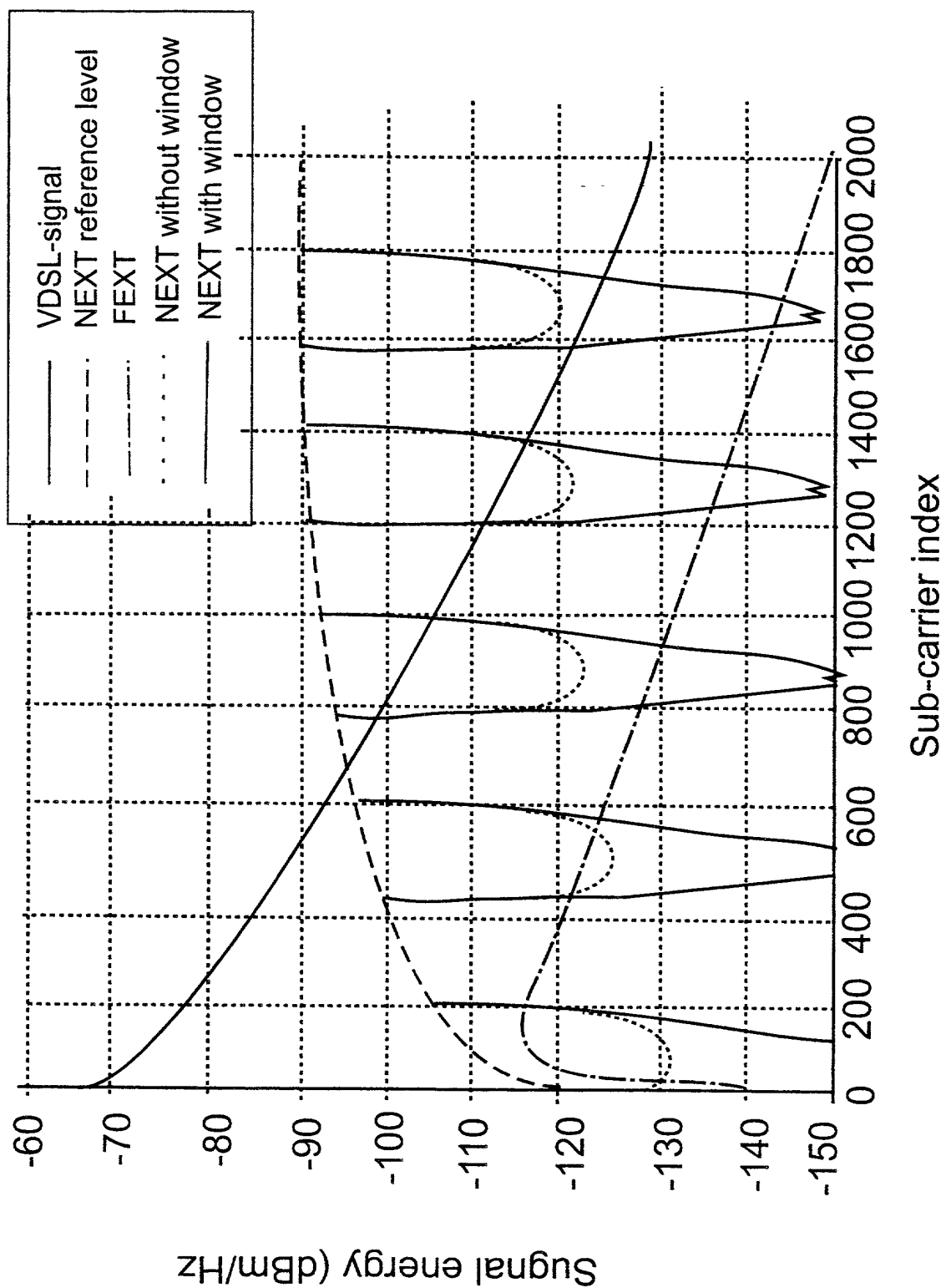
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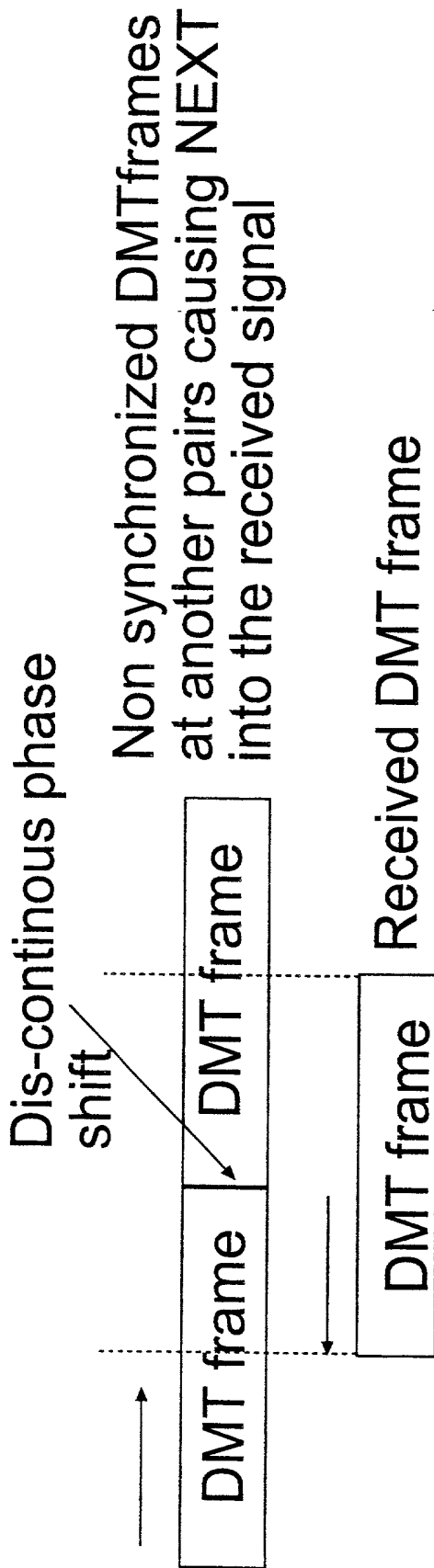
Fig 7

Figure 8

Fig 9

Declaration and Power of Attorney for Patent Application

Déclaration et Pouvoirs pour Demande de Brevet

French Language Declaration

En tant que l'inventeur nommé ci-après, je déclare par le présent acte que:

Mon domicile, mon adresse postale, et ma nationalité sont ceux figurant ci-dessous à côté de mon nom.

Je crois être le premier inventeur original et unique (si un seul nom est mentionné ci-dessous), ou l'un des premiers co-inventeurs originaux (si plusieurs noms sont mentionnés ci-dessous) de l'objet revendiqué, pour lequel une demande de brevet a été déposée concernant l'invention intitulée:

IMPROVEMENTS IN, OR RELATING TO, VDSL

et dont la description est fournie ci-joint à moins que la case suivante n'ait été cochée:

☒ a été déposée le **18 août 2000** sous le numéro de demande des Etats-Unis ou le numéro de demande international **09/622,523**

☐ les spécifications portant le dossier de l'avocat numéro _____

et modifiée le _____
(le cas échéant).

Je déclare par le présent acte avoir passé en revue et compris le contenu de la description ci-dessus, revendications comprises, telles que modifiées par toute modification dont il aura été fait référence ci-dessus.

Je reconnais devoir divulguer toute information pertinente à la brevetabilité, comme défini dans le Titre 37, §1.56 du Code fédéral des réglementations.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

IMPROVEMENTS IN, OR RELATING TO, VDSL

the specification of which is attached hereto unless one of the following boxes is checked:

☒ was filed on **18 AUGUST 2000** as United States Application Number or International Number **09/622,523**

☐ the specification of which bears attorney docket No. _____

and was amended on _____
(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

Page 1 of 6

PTO/SB/105(Rev. 5-95) OMB 0651-0032

French Language Declaration

Je revendique par le présent acte avoir la priorité étrangère, en vertu du Titre 35, §119(a)-(d) ou § 365(b) du Code des Etats-Unis, sur toute demande étrangère de brevet ou certificat d'inventeur ou, en vertu du Titre 35, § 365(a) du même Code, sur toute demande internationale PCT désignant au moins un pays autre que les Etats-Unis et figurant ci-dessous et, en cochant la case, j'ai aussi indiqué ci-dessous toute demande étrangère de brevet, tout certificat d'inventeur ou toute demande internationale PCT ayant une date de dépôt précédant celle de la demande à propos de laquelle une priorité est revendiquée.

Prior foreign application(s)
Demande(s) de brevet antérieure(s)

PCT/SE99/00210	PCT
(Number)	(Country)
(Numéro)	(Pays)

9800539-0	SWEDEN
(Number)	(Country)
(Numéro)	(Pays)

9801150-5	SWEDEN
(Number)	(Country)
(Numéro)	(Pays)

Je revendique par le présent acte tout bénéfice, en vertu du Titre 35 §119(e) du Code des Etats-Unis, de toute demande de brevet provisoire effectuée aux Etats-Unis et figurant ci-dessous.

(Application No.)	(Filing Date)
(N° de demande)	(Date de dépôt)

(Application No.)	(Filing Date)
(N° de demande)	(Date de dépôt)

Je revendique par le présent acte, le bénéfice, en vertu du Titre 35 § 120 du Code des Etats-Unis, de toute demande de brevet effectuée aux Etats-Unis, ou en vertu du Titre 35, § 365(c) du même Code, de toute demande internationale PCT désignant les Etats-Unis et figurant ci-dessous et, dans la mesure où l'objet de chacune des revendications de cette demande de brevet n'est pas divulgué dans la demande antérieure américaine ou internationale PCT, en vertu des dispositions du premier paragraphe du Titre 35, § 112 du Code des Etats-Unis, je reconnais devoir divulguer toute information pertinente à la brevetabilité, comme défini dans le Titre 37, § 1.56 du Code Fédéral des réglementations, dont j'ai pu disposer entre la date de dépôt de la demande antérieure et la date de dépôt de la demande nationale ou internationale PCT de la présente demande:

(Application No.)	(Filing Date)
(N° de Demande)	(Date de Dépôt)

(Application No.)	(Filing Date)
(N° de Demande)	(Date de Dépôt)

Je déclare par le présent acte que toute déclaration ci-incluse est, à ma connaissance, véridique et que toute déclaration formulée à partir de renseignements ou de suppositions est tenue pour véridique; et de plus, que toutes ces déclarations ont été formulées en sachant que toute fausse déclaration volontaire ou son équivalent est passible d'une amende ou d'une incarcération, ou des deux, en vertu de la Section 1001 du Titre 18 du Code des Etats-Unis, et que de telles déclarations volontairement fausses risquent de compromettre la validité de la demande de brevet ou du brevet délivré à partir de celle-ci.

I hereby claim foreign priority under Title 35, United States Code, §119(a)-(d) or § 365(b) of any foreign applications(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below, and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

	Priority not claimed
	Droit de priorité non revendiqué
17 FEBRUARY 1999	☐
(Day/Month/Year Filed)	
(Jour/Mois/Année de dépôt)	
21 FEBRUARY 1998	☐
(Day/Month/Year Filed)	
(Jour/Mois/Année de dépôt)	
1 APRIL 1998	☐
(Day/Month/Year Filed)	
(Jour/Mois/Année de dépôt)	

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or § 365(c) of any PCT international application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Status)(Patented, pending abandoned)
(Statut)(breveté, en cours d'examen, abandonné)

(Status)(Patented, pending abandoned)
(Statut)(breveté, en cours d'examen, abandonné)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

French Language Declaration

POUVOIR: En tant que l'inventeur cité, je désigne par la présente l'(les) avocat(s) et/ou agent(s) suivant(s) pour qu''il(s) poursuive(nt) la procédure de cette demande de brevet et traite(nt) toute affaire s'y rapportant avec l'Office des brevets et des marques: *(mentionner le nom et le numéro d'enregistrement).*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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Page 3 of 6

French Language Declaration	
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Nationalité	Citizenship **Swedish**
Adresse Postale	Post Office Address **Hagaplan 7**
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